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(56) Documents Cited
GB 2293509 A EP 0304147 A2 WO 97/24789 A1
US 4882547 A

(58) Field of Search
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(54) Abstract Title
**Reducing splatter from TDMA transmitter**

(57) A radio transmitter (eg TDMA) has variable gain elements 64 and 72 which are varied during a training routine in dependence on out of band detection at 63 so as to reduce splatter.

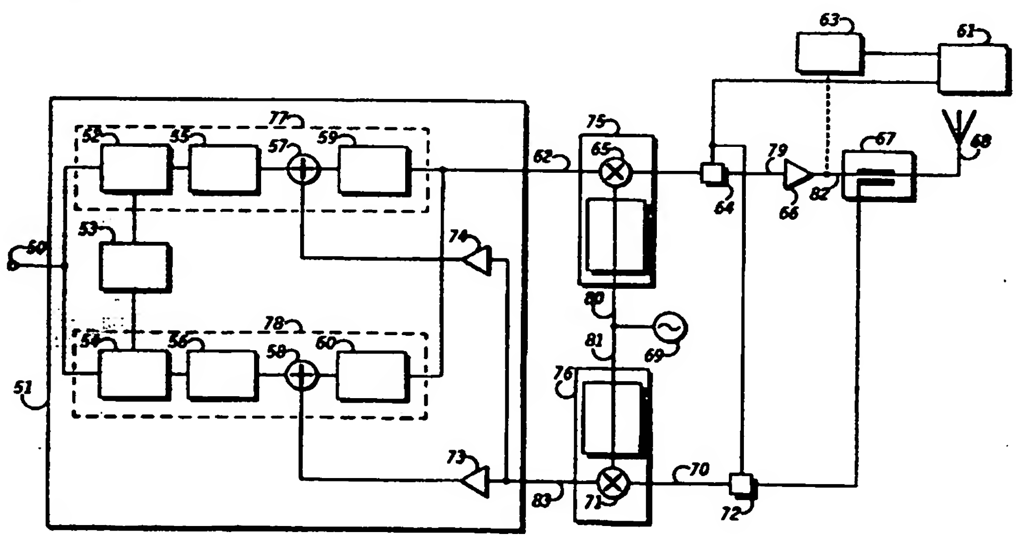


*FIG.3*

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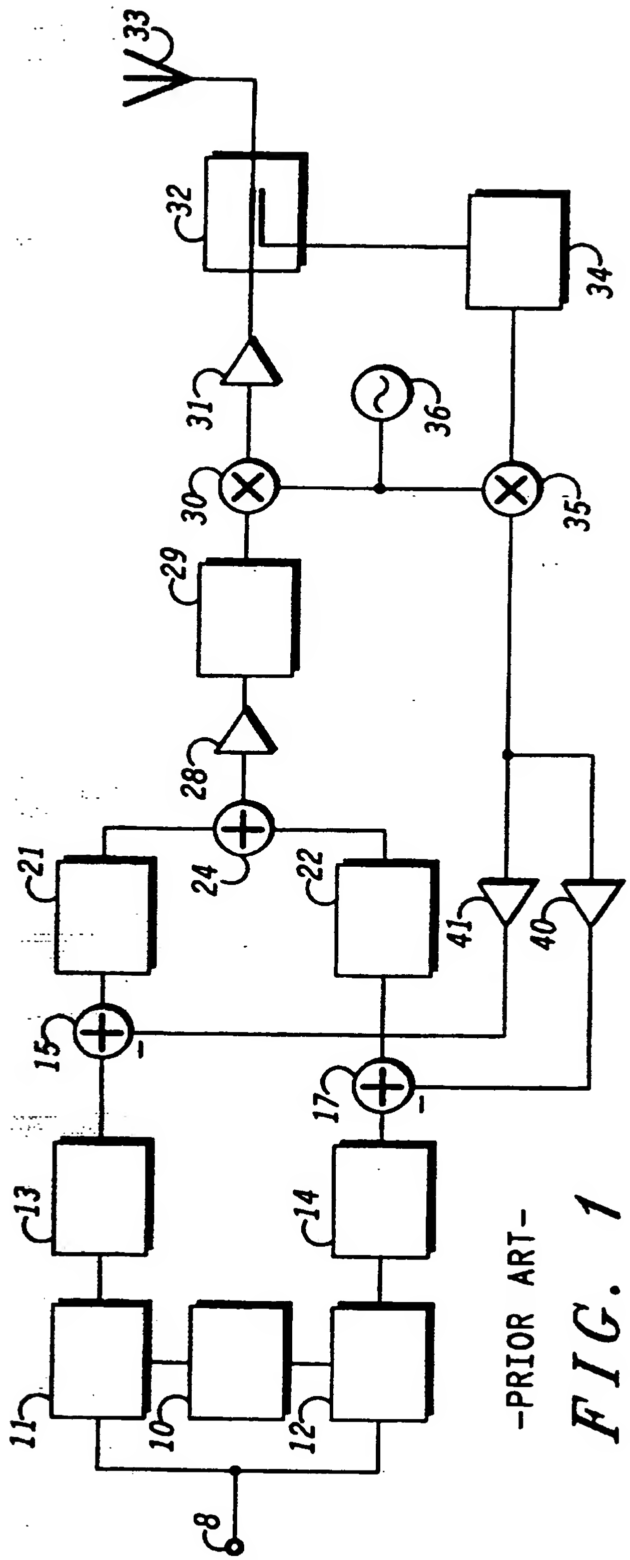
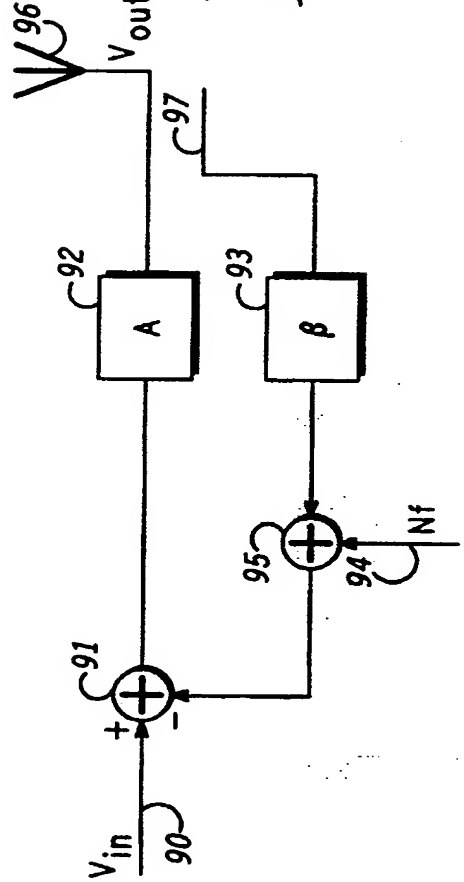



-PRIOR ART-

FIG. 1




-PRIOR ART-

FIG. 2

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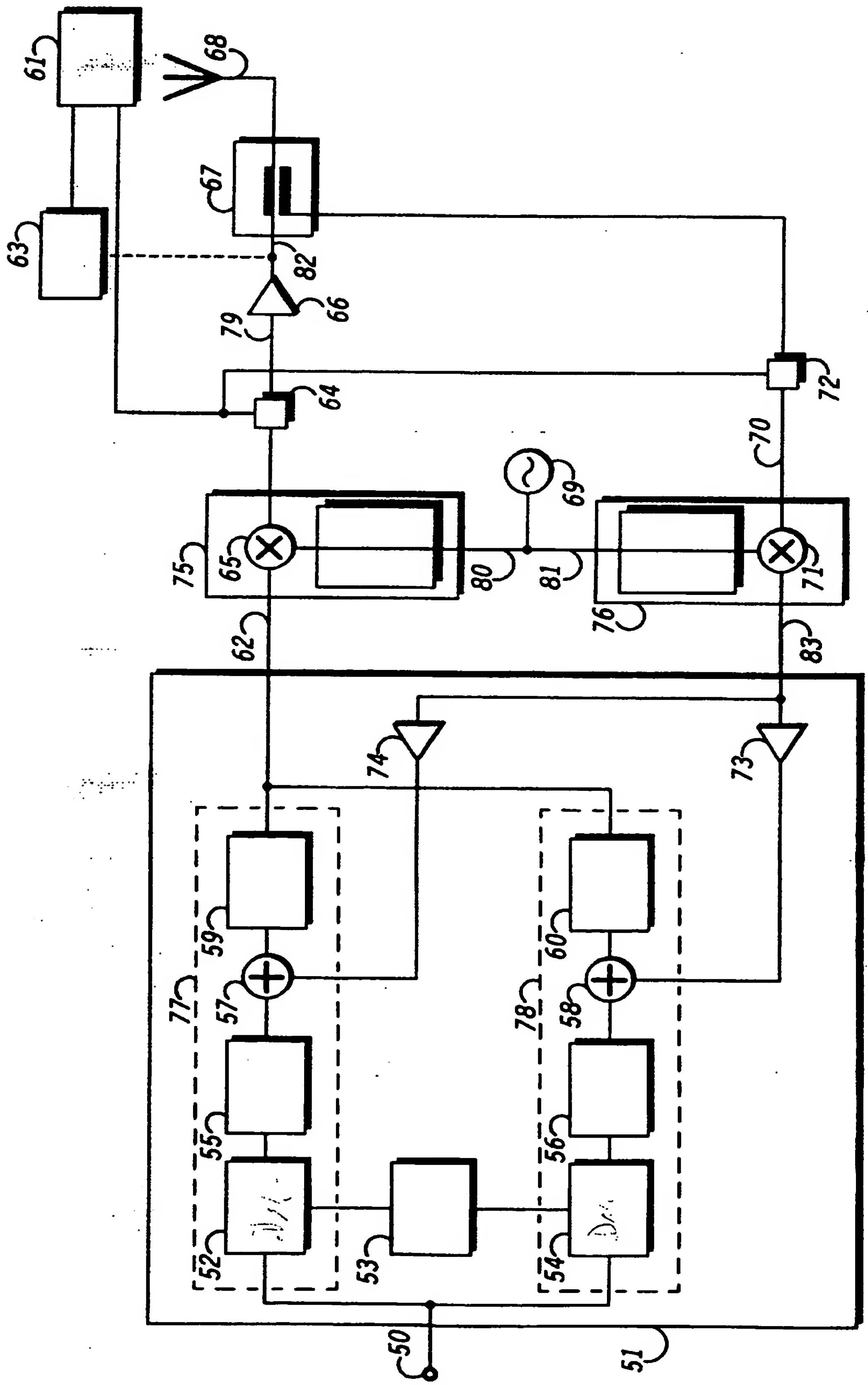
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FIG. 3

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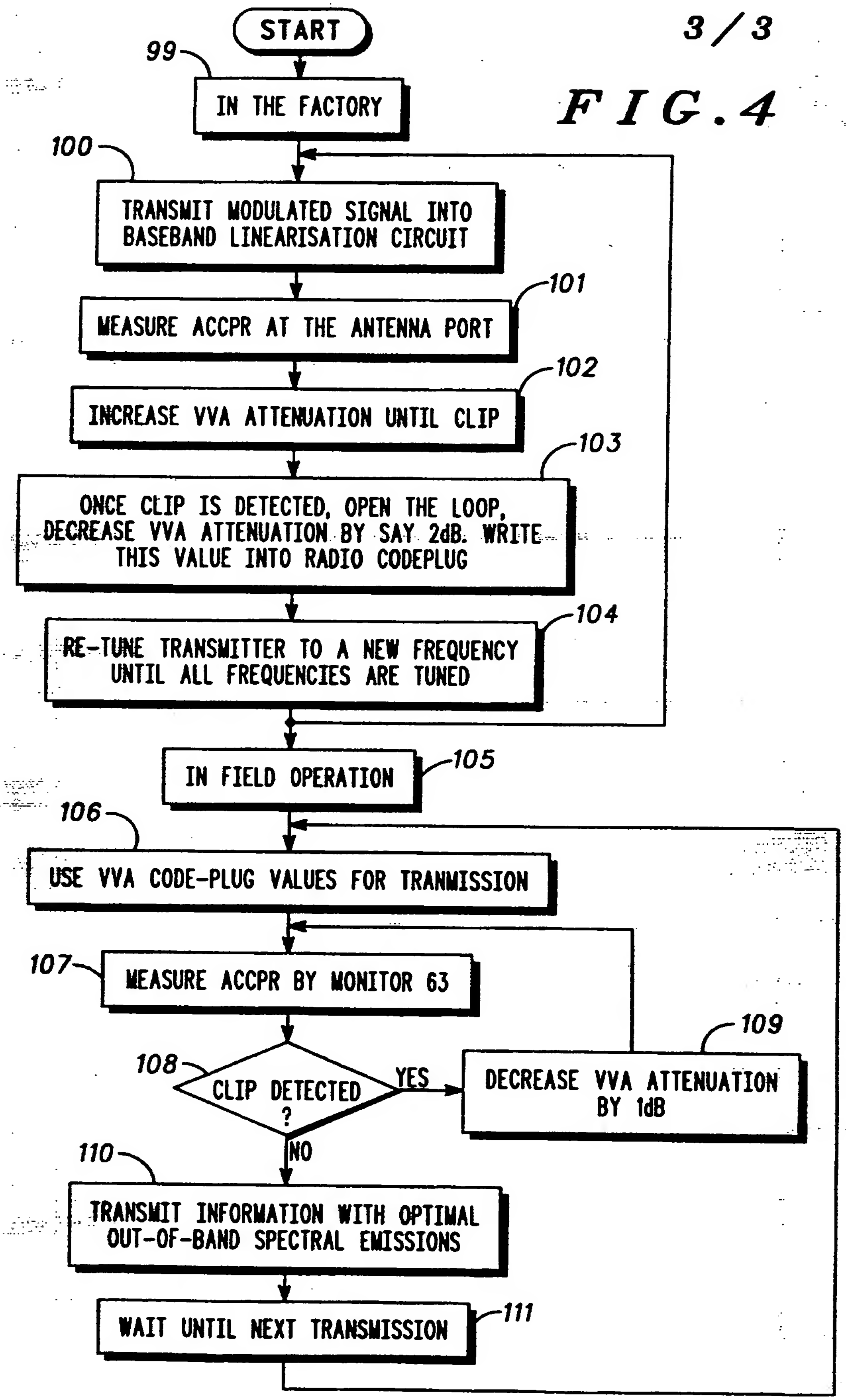
FIG.4



START
99
IN THE FACTORY
100
TRANSMIT MODULATED SIGNAL INTO BASEBAND LINEARISATION CIRCUIT
101
MEASURE ACCPR AT THE ANTENNA PORT
102
INCREASE VVA ATTENUATION UNTIL CLIP
103
ONCE CLIP IS DETECTED, OPEN THE LOOP, DECREASE VVA ATTENUATION BY SAY 2dB. WRITE THIS VALUE INTO RADIO CODEPLUG
104
RE-TUNE TRANSMITTER TO A NEW FREQUENCY UNTIL ALL FREQUENCIES ARE TUNED
105
IN FIELD OPERATION
106
USE VVA CODE-PLUG VALUES FOR TRANMISSION
107
MEASURE ACCPR BY MONITOR 63
108
CLIP DETECTED ?
YES
NO
109
DECREASE VVA ATTENUATION BY 1dB
110
TRANSMIT INFORMATION WITH OPTIMAL OUT-OF-BAND SPECTRAL EMISSIONS
111
WAIT UNTIL NEXT TRANSMISSION

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# TRANSMITTER AND METHOD OF OPTIMISING THE TRANSMITTER PERFORMANCE

## Field of the Invention

This invention is related to radio transmitter designs and, in particular, to linear transmitter designs and their operation in time division multiple access (TDMA) communications systems. The invention is applicable to, but not limited to, reduction of interference in such TDMA communications systems.

## Background of the Invention

The rapid development of digital communications systems, coupled with the increasing performance gains and complexity associated with the signal processing integrated circuits (ICs) required to provide for such systems, has generated a new era of communication problems to be solved. Such systems are designed to communicate ever more information within the available resources of frequency and/or time. In Time Division Multiple Access (TDMA) communications systems, linear transmitters are often used to facilitate transmission of more information within a given frequency bandwidth, but as a consequence tend to transmit more interfering power into the adjacent frequency channels (often termed splatter). The level of such adjacent channel interference is typically due to either (I) the type of linear transmitter technology used and/or (ii) the inherent noise levels associated with the complex ICs.

Standard radio transmitter amplifiers operating in a class 'A' mode are inherently inefficient and therefore linearisation techniques are typically used to improve the transmitting efficiency. This is particularly the case for portable applications where battery life is a critical factor. Some international communications standards, e.g. the European Telecommunications Standard Institute's (ETSI) TErrestrial Trunked RAdio (TETRA) standard, have set stringent limits for adjacent channel coupled power ratio (ACCPR) and wideband noise level performance, namely the aforementioned transmitter interference permitted in adjacent

frequency channels. These stringent performance limits conflict with the requirement to transmit more information in less resource.

This invention seeks to provide a method for reducing adjacent channel interference of linearised transmitters and a linearised transmitter circuit to facilitate such a reduction.

## Summary of the Invention

According to a first aspect of the preferred embodiment of the invention, a method for optimising adjacent channel transmissions of a transmitter circuit is provided. The transmitter circuit includes a baseband processing circuit, whose output is connected to a monitoring circuit and a variable amplifier, wherein the variable amplifier is operably coupled back to the baseband processing circuit via a feedback loop. The method includes the steps of: transmitting a signal from the baseband circuit; monitoring the wideband nature of the signal output from the baseband circuit; and adjusting the variable amplifier in such a manner as to reduce wideband transmissions from the linearised transmitter circuit. Preferably, the transmitter circuit is a linearised transmitter circuit and the step of monitoring the wideband nature of the signal output from the baseband circuit is performed whilst the feedback loop is open and is performed during factory set-up of the radio.

In the preferred embodiment of the invention, the transmitter circuit further includes a power amplifier operably coupled to the variable amplifier such that the power amplifier output provides a signal into the feedback loop and adjustment of the variable amplifier limits the non-linear nature of the linearised transmitter circuit to the baseband processing circuit. Furthermore, the step of monitoring the wideband nature of the signal, output from the baseband circuit, includes monitoring the signal output from the baseband linearisation circuit to determine a signal-to-noise value.

Advantageously, in the preferred embodiment of the invention, the determination of the signal-to-noise value helps to set the variable amplifier to a level that minimises out-of-band transmissions.

Furthermore, in the preferred embodiment of the invention, the method further includes the steps of increasing a ramp signal input to the baseband linearisation circuit, determining the voltage variable attenuator value when saturation of the power amplifier occurs, comparing the determined voltage variable attenuator value to a predetermined second voltage variable attenuator value and selecting the highest voltage variable attenuator value to use for subsequent transmissions from the transmitter. In this manner, the circuit can be optimised for transmissions during the manufacturing process. Subsequently, when the method is performed in use and the transmitter performance changes due to say, ageing of components, environmental conditions, etc., the transmitter can adapt its out-of-band performance accordingly.

In a second aspect of the preferred embodiment of the invention a linearised transmitter circuit is provided for reducing out-of-band interference. The linearised transmitter circuit includes a baseband linearisation circuit having a baseband input and provides a filtered baseband output signal and a monitoring circuit for monitoring the baseband output signal. A variable gain element is provided for receiving the filtered baseband output signal and for providing an output signal and a feedback circuit for receiving at least a portion of the output signal and coupling a feedback signal to the baseband linearisation circuit. A controller is operably coupled to the variable gain element for adjusting the gain of the variable gain element in response to the monitored baseband output signal, so as to reduce out-of-band transmissions.

In the preferred embodiment of the invention, the linearised transmitter circuit includes a power amplifier, operably coupled to the baseband linearisation circuit and the feedback circuit, for receiving a high frequency output signal and for providing a transmitter circuit output. Adjustment of the variable gain element ensures that the baseband processing circuit is the limiting non-linearity factor of the linearised transmitter circuit. Preferably, a combined power gain of a forward path to the feedback path of the transmitter circuit is substantially constant thereby maintaining a constant power gain of the feedback loop of the linearised transmitter circuit.

A preferred embodiment of the invention will now be described, by way of example only, with reference to the drawings.

## Brief Description of the Drawings

FIG. 1 shows a block diagram of a prior art Cartesian feedback linearised transmitter circuit.

FIG. 2 shows a block diagram of a simplified theoretical model of the Cartesian feedback transmitter.

FIG. 3 is a block diagram of a Cartesian feedback linearised transmitter circuit, in accordance with a preferred embodiment of the invention.

FIG. 4 is a flow chart detailing a method for optimising the performance of a radio transmitter to minimise adjacent channel transmissions, in accordance with the preferred embodiment of the invention.

## Detailed Description of the Drawings

Referring first to FIG. 1, a block diagram of a prior art Cartesian feedback linearised transmitter circuit is shown. The linearised transmitter circuit is part of a communications unit, i.e. a radio transmitter, and comprises a digital input signal 8, operably coupled to a digital signal processor (DSP) 10, a digital to analog converter (D/A) for an in-phase (I) channel 11, and a D/A for a quadrature (Q) channel 12. The I channel 11 is operably coupled to an input attenuator 13, which in turn is operably coupled to a summing junction 15 and thereafter a loop filter 21. The Q channel 12 is operably coupled to an input attenuator 14, which in turn is operably coupled to a summing junction 17 and thereafter a loop filter 22.

The linearised transmitter circuit further includes within a low frequency portion of the circuit, a summing junction 24 for combining the output from the Q-channel loop filter 22 and I-channel loop filter 21, connected to a low pass filter 28, and thereafter to an up-conversion forward step attenuator 29. A high frequency portion of the circuit includes a mixer

30 connected to the up-conversion forward step attenuator 29, connected to a power amplifier 31, and connected thereafter to an antenna 33 and a coupler 32. The coupler 32 provides a feedback path by connection to a down converter feedback step attenuator 34 and a down-mixer 35, provided a down-mixing signal by a main local oscillator (LO) 36. The low frequency portion of the feedback circuit consists of a baseband amplifier 41 for the I-channel operably coupled to the I-channel summing junction 15 and a baseband amplifier 40 operably coupled to the Q-channel summing junction 17.

In operation, a digital input signal 8 is fed into both the I and Q D/A converters to provide I and Q baseband analog signals which are attenuated by input attenuator 13 and input attenuator 14 respectively. The filtered analog signals are then combined at summing junction 15 and summing junction 17 respectively with real-time fedback signals to provide linearised baseband I and Q signals. The linearised baseband I and Q signals are input to loop filter 21 and loop filter 22 respectively and then combined to provide a single baseband linearised signal. The single baseband linearised signal is filtered by low pass filter 28 and attenuated by the up-conversion forward step attenuator 29 to provide an attenuated baseband linearised signal.

The attenuated baseband linearised signal is up-converted to a suitable radio frequency by the mixer 30 and main local oscillator (LO) 36, where it is amplified by the power amplifier 31. The amplified linearised radio signal is sampled by the coupler 32 and the sampled signal fed via the down converter feedback step attenuator 34 to the down-mixer 35 to produce a baseband fedback signal. The down converted signal is divided and input to baseband amplifier 41 for the I channel and to the baseband amplifier 40 for the Q channel in order to close the real-time feedback loop.

The combined attenuation of up-conversion forward step attenuator 29 and down-converter feedback step attenuator 34 are complementary and are typically set to be 20 dB. This ensures that the open-loop gain is constant regardless of the power control state, which is kept constant during the whole of the transmission in the TX slot.

A problem associated with such a transmitter operating in a TDMA communications system is that the transmitted power, leaked into adjacent

frequency channels and more particularly the out-of-band channels, is high.

Linear transmitters often use negative feedback techniques, e.g. the Cartesian feedback circuit of FIG. 1, to achieve high linearity of the transmitted output spectrum and thereby minimise adjacent channel splatter generated by say, linearising the more efficient, but inherently less linear class AB Power Amplifier (PA) as compared to class 'A' PAs. The Cartesian feedback loop operates in a closed-loop arrangement. In such an arrangement the non linear RF class AB PA and the feedback signal are negatively combined with the input signal at a baseband frequency in its quadrature 'I' and 'Q' form. The PA's linearity performance improves proportionally to the loop-gain when the loop is closed.

Referring now to FIG. 2, a block diagram of a simplified theoretical model of the Cartesian feedback transmitter. The simplified theoretical model of the Cartesian feedback transmitter includes the following components: an input signal Vin 90 connected to a forward summing junction 91, in turn connected to a forward gain element 'A' 92. The forward gain element 92 provides a transmitter output signal Vout 96, which, in turn, is connected to a coupler 97 for providing a feedback signal to a feedback gain element 'β' 93, and thereafter to a feedback summer 95 and a feedback additive noise signal Nf 94.

In operation, the feedback additive noise signal Nf 94 represents the noise that is dominant in the adjacent frequency channel.

The transfer function from the feedback additive noise signal Nf 94, in closed loop operation, at the transmitter output Vout 96 is:

$$\frac{V_{out}}{V_{in}} = \frac{A}{1 + \beta . A} = \frac{V_{out}}{Nf} \qquad (1)$$

where :

A - Forward path gain: $A_{(IC)} + A_{(\text{driver stage})} + A_{(\text{power amplifier})}$

β - Feedback path gain

Inside the loop bandwidth $\beta A >> 1$ the transfer function can be approximated as:

$$\frac{V_{out}}{V_{in}} = \frac{1}{\beta} = \frac{V_{out}}{Nf} \qquad (2)$$

Outside the loop bandwidth $\beta A << 1$ the transfer function can be approximated as:

$$\frac{V_{out}}{V_{in}} = A \qquad (3)$$

When the power control state is changed from the higher power state in to the lower power state, the feedback gain $\beta$ is increased by a complementary amount to compensate for the decrease in power gain. Thus the feedback noise contribution at the adjacent channel is effectively decreased by say, 5 dB and the ACCPR performance is improved by say, 5 dB.

Referring now to FIG. 3, a block diagram of a Cartesian feedback linearised transmitter circuit, in accordance with the preferred embodiment of the invention is shown. The linearised transmitter circuit is designed such that adjacent channel transmissions, and in particular wideband noise transmissions, are reduced. The linearised transmitter circuit includes a baseband linearisation circuit 51 having a baseband input 50 providing a filtered output 62. The baseband linearisation circuit 51 includes an in-phase (I) channel 77 having a digital to analog converter (D/A) 52, operably coupled to an input attenuator 55, and thereafter to an summing junction 57 and a loop filter 59. A feedback signal is input to the I-channel at the summing junction 57 via a baseband amplifier 74. The baseband linearisation circuit 51 also includes a quadrature (Q) channel 78 having a digital to analog (D/A) converter 54, operably coupled to an input attenuator 56, and thereafter to an summing junction 58 and a loop filter 60. A feedback signal is input to the Q-channel at the summing junction 58 via a baseband amplifier 73. A digital signal processor (DSP) 53 is also provided within the baseband linearisation circuitry 51.

The linearised transmitter circuit also includes a frequency up-conversion circuit 75, for receiving the filtered output 62 and for providing an up-converted signal to a voltage variable attenuator 64. The voltage variable attenuator 64, attenuates the signal received from the frequency up-conversion circuit 75 and provides a high frequency output 79 to a power amplifier 66. The power amplifier 66 provides an amplified up-converted signal to the baseband monitor 63, whose output is connected to the voltage control element 61. The voltage control element controls the attenuation setting of the voltage variable attenuator 64 and second voltage variable attenuator 72. The power amplifier output 82 is fed to a sampling circuit 67, e.g. a coupler, and then an antenna 68. The sampling circuit 67 provides a feedback signal 70 to a frequency down-conversion circuit 76, via the second voltage variable attenuator 72. A frequency up-conversion signal 80 and a frequency down-conversion signal 81 are provided by a main local oscillator 69. The frequency down-conversion circuit 76 provides a low frequency output 83 which is fed to a baseband amplifier 73 and baseband amplifier 74, within the baseband linearisation circuitry 51.

In operation, the baseband input 50 is fed into the baseband linearisation circuit 51, divided into two signals in quadrature to each other and input to I-channel 77 and Q-channel 78 respectively. In each respective channel the input signal is converted from a digital signal to an analog signal by the D/A 52 in I-channel 77 and D/A 54 in Q-channel 78. The analog signals are attenuated by the input attenuator 55 and input attenuator 56, summed with fedback signals at the summing junction 57 and summing junction 58, and filtered by loop filter 59 and loop filter 60 respectively. The signals from the I-channel output and Q-channel output are combined to provide a filtered output 62. The filtered output signal 62 is up-converted via frequency up-conversion circuit 75, and amplified by power amplifier 66. The amplified up-converted output 82 is monitored by the baseband monitor 63, to determine the adjacent channel coupled power ratio (ACCPR) and/or signal-to-noise performance of signals leaving the baseband linearisation circuit 51. The baseband monitor 63 is preferably connected to the voltage control element 61 for setting the voltage variable attenuator 64, in accordance with the monitored ACCPR and/or signal-to-noise level. The output from the voltage variable attenuator is input to the

power amplifier 66 which amplifies the attenuated signal and provides the transmitter circuit output 82.

The sampling circuit 67 couples off a portion of the transmitter circuit output 82 and inputs the fedback signal to the second voltage variable attenuator 72. The second voltage variable attenuator 72 provides the feedback signal 70 to the frequency down-conversion signal 81 where it is mixed with the feedback signal 70, at the mixer 71, to provide the low frequency feedback signal 83. Preferably the optional second voltage variable attenuator 72 adjusts the power level of the low frequency feedback signal 83 and is also controlled by the voltage control element 61. The low frequency output 83 is divided and input to the I channel 77 via the baseband amplifier 74 and input to the Q channel 78 via the baseband amplifier 73 in order to close the real-time feedback loop. An advantage of placing a second voltage variable attenuator 72 in the feedback path is that the noise inside the loop bandwidth can also be optimised.

In the preferred embodiment, the linearised transmitter circuit is a Cartesian feedback linearised transmitter circuit although it is within the contemplation of the invention that other linearised transmitter technologies, such as Adaptive Pre-distortion, benefit from the inventive concept. It is also within the contemplation of the invention that alternative topologies and arrangements for adjusting the gain of signals can be used.

In operation, in order to maintain the required linearity, low spectral output across the out-of-band frequencies, and an optimised efficiency of the radio transmitter, it is necessary to tune the drive level to be below a clip (saturation) level and maximise the signal to noise ratio of the signal exiting the baseband linearisation circuit 51. The preferred method is to use a training ramp at the baseband input that increases the signal output from the power amplifier 66 until clipping of the power amplifier output is detected by comparing the loop error to a level that indicates clip. The ramp's input level is sampled at the time that clip is detected and the data input level is adjusted to be below clip. The slope of the ramp is calibrated so that the clip will occur.

Before the clip occurs, the loop error voltage is typically a small constant value $V_{norm\_error}$. When the clip occurs, the loop error voltage rises rapidly until it reaches $V_{threshold}$ and the clip is detected. The voltage of the analog ramp is then sampled and held. At the same time, the

DSP outputs a constant signal level. The signal from the DSP is compared with the sampled value of the analog ramp and using a successive approximation algorithm, the variable attenuator is set to value at which the DSP signal is equal to the held ramp signal. After the clip is detected and the ramp value is sampled and held, the ramp is disabled.

Then the variable attenuator value that was set during the training routine is compared with the value of the variable attenuator in the code-plug of the radio. The value of the variable attenuator in the code plug of the radio is set during the power tuning in the factory and corresponds to the optimum radio output power, for example as specified by the radio standard. The radio software selects the larger of the two values and uses it for the "non-training" slots, i.e. the slots used for transmitting signalling or traffic information.

The power at the output of the Cartesian loop transmitter is set by the amount of gain in the feedback path (β). The power output capability of the transmitter is determined by the capability of the final amplification device, the power amplifier 66. The signal to noise ratio at the output of the transmitter outside the loop bandwidth of the feedback transmitter is limited by the signal to noise of the baseband linearisation circuit 51. Hence, in order to maximise the signal to noise ratio of the transmitter, maintain linearity and maximise the transmitter efficiency, the signal to noise ratio of the baseband linearisation circuit 51 must also be maximised. It is noted that the dominant noise of the baseband linearisation circuit 51, typical in such applications, tends to be of an additive nature.

By monitoring and setting the gain after the baseband processing circuit, the output power, and therefore the signal-to-noise ratio of the output signal, is controlled. This is arranged to ensure that the signal-to-noise of the baseband processing circuit 51 is the limiting factor of the whole transmitter's signal-to-noise ratio, thereby minimising the out-of-band spectral emissions.

To control the output signal-to-noise of the baseband processing circuit, and also optimise the output power level, a voltage variable attenuator 64 (VVA) is used in the forward path of the loop. Preferably the optimal value of the signal level, output from the baseband processing circuit is determined during the radio manufacture or during any radio set-up routine in the factory or in the field. The VVA 64 is preferably tuned

in the factory while the transmitter is in the open loop mode, to ensure that the correct amount of transmit power is supplied at the antenna. The tuning can be performed for a number frequencies and the results stored in, for example, a memory unit or the radio codeplug. Once manufactured, the radio uses the stored VVA 64 values and interpolates the VVA 64 values in between the tuned frequencies.

The above tuning of the VVA 64 guarantees that the limiting non-linear element of the transmitter is the baseband processing circuit 51 (or baseband feedback coupling Integrated Circuit) and not the power amplifier (PA), as it is in conventional transmitter architectures.

Referring now to FIG. 4, a flow chart detailing a method for minimising out-of-band transmissions in a time domain communications system, in accordance with the first aspect of the preferred embodiment of the invention, is shown. The method for minimising the transmissions includes, in the factory in step 99, the step of transmitting a modulated signal into the baseband linearisation circuit 51, as in step 100, and monitoring the signal output from the baseband linearisation circuit 51 at a high frequency coupler/antenna port to determine an adjacent channel coupled power value (ACCPR) and/or signal to noise level output from the baseband linearisation circuit 51, as in step 101. A VVA attenuation is increased until the power amplifier enters a clip region (saturates), as shown in step 102. Once clip is detected, the loop is opened and the level of the variable attenuator decreased by say, 2 dB. The VVA level is then programmed into say, the code-plug of the radio, as shown in step 103. This process is then repeated for each desired frequency, until all of the frequencies of operation have a dedicated and optimised VVA level, as shown in step 104.

In the preferred embodiment of the invention, a different tuning procedure is used in the field, i.e. once the radio is being used. The preferred procedure in the field, as shown in step 105, includes using the VVA code plug values for transmission, as in step 106. The adjacent channel coupled power value (ACCPR) and/or signal to noise level is measured by the monitor 63, as shown in step 107, to determine whether "clip" is detected of the transmitted signal, as in step 108. If clip is detected in step 108, the VVA value is decreased in step 109 and the adjacent

channel coupled power value (ACCPR) and/or signal to noise level is measured by the monitor 63. This loop back is preferably a continuous iterative process to further optimise the VVA value for transmission, although it does not need to be. If clip is not detected in step 108, information is transmitted with optimal out-of-band spectral emissions, as shown in step 110, and the process waits until the next transmission, as in step 111, before the VVA code plug values are used again for transmission, as in step 106.

An alternative method of optimising the VVA includes, opening the loop whilst monitoring the on-channel power level and tuning the VVA value to a pre-determined level, based on the desired output level and desired out-of band performance, for that level. Preferably, this method would also be carried out over the frequency range of interest. This method is advantageous when the clip level is more or less stable for the radio(s) being tuned.

Advantageously, in the preferred embodiment of the invention, this method can reduce out-of-band transmissions in a Cartesian feedback linearised transmitter circuit by at least 10 dB.

## Claims

1. A method for optimising adjacent channel transmissions of a transmitter circuit having a baseband processing circuit, whose output is connected to a monitoring circuit and a variable amplifier wherein the variable amplifier is operably coupled back to the baseband processing circuit via a feedback loop, the method comprising the steps of:

transmitting a signal from the baseband circuit;

monitoring the wideband nature of the signal output from the baseband circuit; and

adjusting the variable amplifier in such a manner as to reduce wideband transmissions from the transmitter circuit.

2. The method of claim 1, wherein the step of monitoring the wideband nature of the signal output from the baseband circuit is performed whilst the feedback loop is open.

3. The method of claim 1 or 2, wherein the transmitter circuit is a linearised transmitter circuit and further comprises a power amplifier operably coupled to the variable amplifier such that the power amplifier output provides a signal into the feedback loop and adjustment of the variable amplifier limits the non-linear nature of the linearised transmitter circuit to the baseband processing circuit.

4. The method for optimising adjacent channel transmissions according to any one of claims 1, 2 or 3, wherein the step of monitoring the wideband nature of the signal output from the baseband circuit includes monitoring the signal output from the baseband circuit to determine a signal-to-noise value.

5. The method for optimising adjacent channel transmissions according to claim 3 or 4, the method further comprising the steps of:

increasing a ramp signal input to the baseband circuit;

determining the voltage variable attenuator value when saturation of the power amplifier occurs;

comparing the determined voltage variable attenuator value to a predetermined second voltage variable attenuator value; and

selecting the highest voltage variable attenuator value to use for subsequent transmissions for the transmitter.

6. A linearised transmitter circuit for reducing out-of-band interference, the linearised transmitter circuit comprising:

a baseband linearisation circuit having a baseband input and providing a filtered baseband output signal;

a monitoring circuit for monitoring the baseband output signal;

a variable gain element for receiving the filtered baseband output signal and for providing an output signal;

a feedback circuit for receiving at least a portion of the output signal and providing a feedback signal to the baseband linearisation circuit; and

a controller operably coupled to the variable gain element for adjusting the gain of the variable gain element in response to the monitored baseband output signal so as to reduce out-of-band transmissions.

7. The linearised transmitter circuit according to claim 6, further comprising a power amplifier operably coupled to the baseband linearisation circuit and the feedback circuit for receiving a high frequency output signal and providing a transmitter circuit output, wherein adjustment of the variable gain element ensures that the baseband processing circuit is the limiting non-linearity factor of the linearised transmitter circuit.

8. The linearised transmitter circuit according to any of the preceding claims 6 or 7, wherein a combined power gain of a forward path to the feedback path of the transmitter circuit is substantially constant thereby maintaining a constant power gain of the feedback loop of the linearised transmitter circuit.

9. The linearised transmitter circuit according to any of the preceding claims 6 to 8, wherein the baseband input, filtered output and low frequency output comprise two signals in quadrature to each other and the linearised transmitter circuit is a Cartesian feedback linearised transmitter circuit.

10. A linearised transmitter circuit substantially as described herein with respect to FIG. 3 of the drawings.

11. A method for minimising the out-of-band transmissions of a transmitter substantially as described herein with respect to FIG. 4 of the drawings.

The Patent Office

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**Application No:** GB 9720051.3
**Claims searched:** 1-11

**Examiner:** D. Midgley
**Date of search:** 11 February 1998

# Patents Act 1977
# Search Report under Section 17

**Databases searched:**

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): H3G GPQ GPXX H3W WUL WVT WVX

Int Cl (Ed.6): H03F 1/32 1/34 H03G 3/20 H04B 1/04

Other: ONLINE:WPI

**Documents considered to be relevant:**

| Category | Identity of document and relevant passage | | Relevant to claims |
|---|---|---|---|
| X | GB 2293509 A | (MOTOROLA) See, epecially, figure 2, blocks 33 and 34. | 1 AND 6 AT LEAST |
| X | EP 0304147 A2 | (KAHN) | " |
| X | WO 97/24789 A1 | (QUALCOMM) | " |
| X | US 4882547 | (GEN. ELECTRIC) | " |

| | |
|---|---|
| X Document indicating lack of novelty or inventive step | A Document indicating technological background and/or state of the art. |
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